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USING DERIVATIVE PRODUCTS FROM PROCESSING WILD BERRIES TO ENRICH PRESSED SUGAR

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This paper reports a study addressing the issue of enriching pressed sugar in order to improve its biological value. As additives to sugar, the use of derivative products of processing wild berries Hippophaerhamnoides L., Viburnumopulus, Sambucusnigra, Sorbusaucuparia is suggested. The technology of processing wild berries includes their preliminary freezing, partial dehydration by osmotic dehydration, and subsequent drying. The resulting osmotic solution is proposed to be used to moisten sugar before its pressing and drying. An important practical aspect of this technological advancement is the possibility to move away from seasonality at sugar factories. Since it is advisable to process wild berries at the end of the beet processing season. To implement the proposed technology, one can use some available equipment. The chromatographic method was applied to analyze the amino acid spectrum of derivative products from processing wild berries; 17 amino acids were identified in their composition, including essential ones. The highest concentration of amino acids (55.47 mg/100 g) was found in the derivative product of Sambucusnigra processing. The least amount of amino acids passes into the product of processing Viburnumopulus (3.63 mg/100 g). The experiment showed that adding to sugar 10 % of the derivatives of the processed wild berries Hippophaerhamnoides L., Viburnumopulus, Sambucusnigra, Sorbusaucuparia has a positive effect on the organoleptic indicators of the finished product. The highest rating for all organoleptic indicators (appearance, taste and smell, purity of the solution) was given to sugar enriched with a derivative of the Hippophaerhamnoides processing product. It contained only 16 amino acids in the amount of 16.14 mg/100 g. Of the found amino acids, the highest concentration was demonstrated by serine (7.43 mg/100 g). The sugar with the addition of the solution after partial dehydration of Viburnumopulus revealed a slight characteristic smell of the additive. In the sugar with the addition of the derivative product of processing Sorbusaucuparia, a pleasant bitterness was felt, indicating the transition of sorbic acid from the fruit to osmotic solution

Keywords: enriched pressed sugar, osmotic dehydration, derivatives of processing of wild berries, amino acid spectrum

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1. Introduction

Sugar is extremely popular among consumers around the world. It is consumed as a finished product and used as a raw material in the production of many types of food. During the consumption of sugar, the level of glucose in the blood quickly grows, the amount of dopamine in the brain increases. Low sugar levels cause people to feel hungry. At the same time, the use of sugar in large quantities can lead to undesirable consequences and be the cause of many diseases.

In the modern world, there is a need to produce safe products of the highest quality, which have a positive impact on health. Increased consumer interest in these issues is driving changes in the food industry. The research community is working on the development of new technologies and new food products [1]. It is no exception to expand the range of "healthy" sugar enriched with various biologically active additives.

This initiative will not only help the sugar sector diversify its resources to increase added value but also contribute to providing people with useful trace elements [2].

Taking into consideration the fact that for a number of objective reasons, the purchasing power of Ukrainians has significantly decreased, there are some concerns about the feasibility of producing value-added sugar. However, some market research conducted in other countries reveals that consumers are willing to pay more for enriched sugar, given its beneficial properties [3]. Therefore, enriched sugar of Ukrainian production can become an exclusive export commodity.

2. Literature review and problem statement

Depending on the production technique, sugar is divided into crystalline, sucrose for champagne, powdered sugar, and pressed sugar. A variety of additives are added to sugar, to give a bright color and good taste and aromatic properties. Of particular interest to consumers is "natural" sugar. Natural sugar is an untreated (unrefined) brown product that contains macronutrients (potassium, calcium, sodium), trace elements (zinc, copper, iron), vitamins B1 and B2, amino acids (glycine, lysine, and others), mineral salts, biologically active substances. Unlike white sugar, it has a restorative, anti-caries, and anti-sclerotic effect on the human body. The use of the term "natural" increases the value of the product due to a new trend in the consumption of products containing only natural ingredients [4]. Given that the society has been exposed to anti-propaganda about sugar consumption for the last 20 years, the issue of expanding the range of sugar enriched with healthy nutrients is extremely important.

To enrich sugar with retinylpalmitate seeds (RP, vitamin-A), an intermittent crystallization process with cooling was developed [5]. This technology is very complex and long-lasting.

An experimental sugar-containing product with maltodextrin, cane molasses, and Japanese laminaria was devised [6]. The additives offered by the developers are quite expensive. The cited study does not contain information on the approximate cost of such a sugar-containing product. Given the market price of supplements, it can be assumed that the price may double.

It is proposed to use extracts of rose hips, hawthorn, and citrus fruits in a ratio of 2:2:1 in the amount of 10–15 % to enrich sugar. Granulated sugar technology makes it possible to obtain products that have a homogeneous composition and better preserve the native properties of the introduced additives. However, the use of extracts increases energy consumption on the process of drying sugar [7].

There is a well-known technique to obtain crystalline sugar for sports nutrition. The technique involves the introduction of mineral functional components into dissolved sugar and its re-crystallization. However, at the same time, the organoleptic properties of sugar deteriorate, since minerals are included in the crystal lattice [8].

It is known that consumers prefer natural additives rather than synthetic [9]. The use of synthetic additives and the problems associated with their negative impact on health form a negative attitude of consumers, assimilating these compounds with potential carcinogenic and allergenic effects. Plants, fruits, and spices are recognized as the best raw materials for obtaining natural additives due to the presence of compounds beneficial to health in their composition. The composition of plants includes biologically active substances (antioxidants), antimicrobial agents, flavors, dyes, and others [10].

It is worth noting that by-products and related products of processing plant raw materials are not less rich in biologically active molecules. They can be used as supplements such as flavors, sweeteners, and antioxidants [11]. However, the issue of choosing universal methods for extracting biologically valuable components from raw materials is unresolved.

This factor adds to the need to reuse by-products and bio residues obtained from plants as sources of natural additives. The need for innovative solutions for the reuse of waste and by-products is the subject of many studies, including the lack of technologies for processing wild berries and the directions of use of their derivative products [12, 13]. By-products and derivatives have the potential to be reused. The volume of residues that can be used after processing is estimated at millions of tons annually [14]. The residues were estimated but it is not taken into consideration that in addition to waste, related processing products are also formed, which are also of great importance.

An insufficiently studied source of natural dietary supplements are wild berries such as guelder rose (*Viburnumopulus*), sea buckthorn (*Hippophaerhamnoides L.*), elderberry (*Sambucusnigra*), rowan (*Sorbusaucuparia*). Usually, they are used for the production of biologically active additives, and very rarely in the food industry, and especially for the enrichment of sugar. However, it is known that wild berries not only contain a large amount of nutrients but also have good sensory properties. When cultivating them, chemical pest protection and growth stimulants are not used, which makes them environmentally friendly raw materials.

The composition of sea buckthorn berries (*Hippophaerhamnoides L.*) includes essential fatty acids, amino acids, phytosterols and flavonoids, vitamins E (160 mg/100 g), B1, B2, K, carotenoids (314 to 2139 mg/100 g), pigments and lipoproteins [15]. Sea buckthorn oil obtained by mechanical pressing is considered to be a source of many useful elements. The cited studies do not address the issue of recycling or processing of waste generated during pressing.

Viburnumopulus berries are a natural source of ascorbic acid, α tocopherol, carotenoids, chlorophylls, and phenolic compounds [16].

Elderberry (*Sambucusnigra*) is a source of biologically active compounds (flavanols, phenolic acids, proanthocyanidins, and anthocyanins) [17]. However, the cited study did not analyze the amino acid composition of berries and products of their processing. Although it is known that amino acids are extremely important for all biochemical processes in the body.

Although wild rowan (*Sorbusaucuparia*) is acidic in taste, it still contains a wide range of useful components. Rowan berries contain phytochemicals such as vitamins, carotenoids, and phenolic acids, as well as important minerals (iron, potassium, and magnesium). In addition, rowan berries contain sweet-tasted sorbitol sugar, which is slowly metabolized in the human body and therefore suitable as a sweetener for people suffering from diabetes [18].

Earlier studies into the use of wild berries in the food industry have produced positive results. However, there are no studies into the use of wild berries to enrich sugar. Given that sugar is a product that should dissolve, one should choose such a technology for processing berries, which will make it possible to remove useful substances from them without having a negative impact on the organoleptic properties of sugar.

One such technique of processing plant raw materials is osmotic dehydration, a process used to partially release water from plant tissues by immersing in a hypertensive solution. In the case of osmotic dehydration, part of biologically valuable substances, including dye and flavoring substances, passes into the osmotic solution [19]. While reviewing previous studies, it was found that the technology of processing wild raw materials using osmotic dehydration was not investigated. Until now, the possibility of using osmotic solutions to moisten sugar before pressing has not been considered.

Therefore, relevant studies into the use of derivative products of processing wild berries for sugar enrichment should be considered promising.

3. The aim and objectives of the study

The aim of this study is to substantiate the use of derivative products of processing wild berries *Hippophaerhamnoides L., Viburnumopulus, Sambucusnigra, Sorbusaucuparia* to enrich pressed sugar. This will make it possible to increase the biological value of pressed sugar and improve its organoleptic properties.

To accomplish the aim, the following tasks have been set:

– to analyze the amino acid spectrum of derivatives of processing products of wild berries *Hippophaerhamnoides L., Viburnumopulus, Sambucusnigra, Sorbusaucuparia*;

– to conduct an organoleptic assessment of the quality of sugar enriched with derivative products from processing wild berries *Hippophaerhamnoides L., Viburnumopulus, Sambucusnigra, Sorbusaucuparia*.

4. The study materials and methods

The object of our research is osmotic dehydration as a technique that makes it possible to preserve the biological value of plant raw materials as much as possible. The subject of the study is the wild berries *Hippophaerhamnoides L., Viburnumopulus, Sambucusnigra, Sorbusaucuparia*. The main hypothesis of the study assumes that during osmotic dehydration, useful soluble substances, including amino acids, pass into the sugar solution. Using osmotic solutions to moisten sugar before pressing it, one can not only increase its biological value but also provide certain taste and aromatic characteristics.

The technique implied that wild berries were frozen at first, their partial dehydration was carried out in a hypertensive sugar solution (70 %) by osmotic dehydration for 1 hour at a temperature of 50 °C. The liquid thermostat MLW-16 (Germany) was used for osmotic dehydration. After dehydration, the berries were separated from the osmotic solution and dried. The resulting solution, at a temperature of 40–45 °C, was used in the amount of 10 % as a moisturizing base for pressing sugar. The moisture content of sugar before pressing should be in the range of 1.6–3.5 %, and its optimum temperature should be 45–55 °C.

Usually, under industrial conditions, sugar is moistened with syrup or hot artesian water before pressing. The thoroughly agitated mixture of osmotic solution and sugar was placed in silicone molds, pressed by hand, and dried in a convective laboratory dryer at a temperature of 80–85 °C.

To establish the biological value of derivative products from processing wild berries, an analysis of their amino acid spectrum was carried out. The identification of the amino acid spectrum was carried out by the method of ion exchange column chromatography using the amino acid analyzer "BIOTRONIK" (Germany).

The organoleptic assessment of enriched sugars was carried out on a certain number of descriptors (Table 1) using a ten-point scale according to the averaged data.

Table 1

Organoleptic indicators of enriched sugar

Indicator	Characteristic
Appearance	The color is characteristic of the color of the additive
Smell and taste	Sweet with a slight odor and taste of the appropriate natural additive
The purity of the solution	The sugar solution must be such that it has a weak opalescence without insoluble precipitate, mechanical and other impurities

Since the state standard for sugar (DSTU 4623-2006) and the international standard (ICUMSA 150) lack characteristics that would describe enriched sugar, the descriptors of organoleptic evaluation were formed independently. At the same time, organoleptic indicators of pressed sugar were taken into consideration. The organoleptic evaluation was carried out by non-professional tasters of different age and gender (10 people). Each participant was instructed to take two sensory tests: testing crystalline pressed sugar and its solutions. Each test was conducted on two different days from 9:00 to 10:30 (at least 2 hours after breakfast). In addition, the respondents were instructed not to smoke or drink coffee 60 minutes before the test [20]. All organoleptic tests were conducted in the tasting room of the nutrition technology laboratory at Sumy National Agrarian University and were completed by 11 a.m.

5. Results of studying the feasibility of using the derivative products from processing wild berries to enrich sugar

5. 1. Results of studying the amino acid spectrum of derivative products from processing wild berries

Our analysis of the amino acid spectrum of derivative products from processing the wild berries *Hippophaerhamnoides L., Viburnumopulus, Sambucusnigra, Sorbusaucuparia* showed the presence of amino acids in their composition (Fig. 1–4).

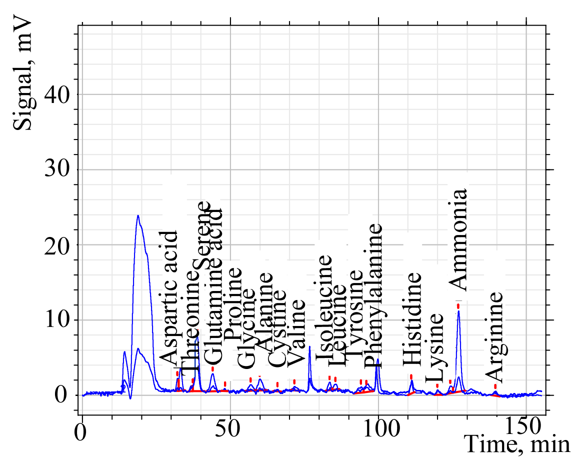

Fig. 1. Amino acid spectrum of the derivative product from processing *Viburnumopulus*

In the derivative product from processing the *Viburnumopulus* berries, we identified 7 essential amino acids (Fig. 1). 1), mg/100 g: valine (0.08), leucine (0.1), isoleucine (0.14), lysine (0.09), histidine (0.18), threonine (0.08), phenylalanine (0.13). At the same time, the total amount of amino acids was 3.63 mg/100 g. The highest concentration of the total number of amino acids was demonstrated by serine (0.94 mg/100 g) and glutamic acid (0.54 mg/100 g).

Glutamic acid has the properties of a preservative, its derivatives render a stabilizing effect to products during storage. Additionally, glutamic acid is a flavor enhancer.

From the Hippophaerhamnoides berries, 16 amino acids (Fig. 2) pass into osmotic solution in the amount of 16.14 mg/100 g, of which the highest concentration is demonstrated by serine (7.43 mg/100 g), proline (2.51 mg/100 g), and aspartic acid (2.2 mg/100 g). Among the essential amino acids, the sea buckthorn processing product has the largest amount of phenylalanine (0.57 mg/100 g), which is a precursor to tyrosine, signal monamineudopamine, adrenaline, and norepinephrine, as well as melanin skin pigment.

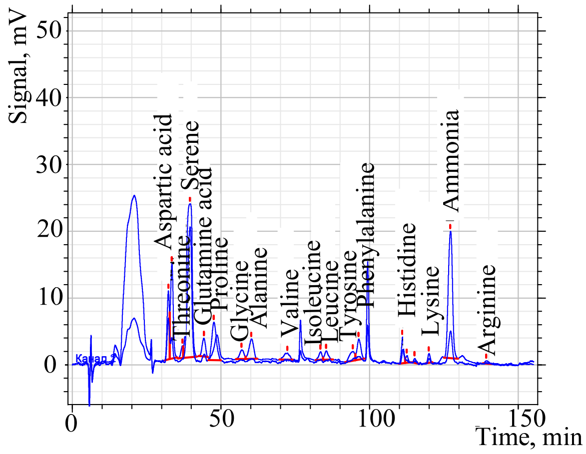

Fig. 2. Amino acid spectrum of the derivative product from processing *Hippophaerhamnoides L.*

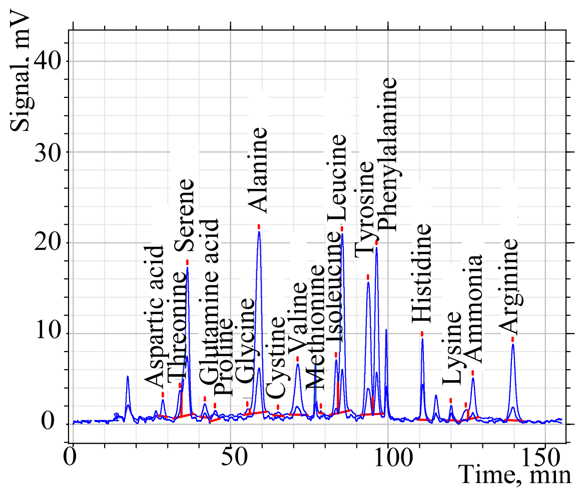

Fig. 3. Amino acid spectrum of the derivative product from processing *Sambucusnigra*

The amino acid spectrum (Fig. 3) of the processing product from *Sambucusnigra* berries showed the presence of 17 amino acids (55.47 mg/100 g). In this product, all essential amino acids were found. Including, mg/100 g, valine (2.86), leucine (7.49), isoleucine (1.81), lysine (0.53), histidine (2.79), threonine (0.97), phenylalanine (7.52), methionine (0.03). The highest concentration of semi-replaceable amino acid tyrosine (9.3 mg/100 g) was detected. From elderberry, a fairly large amount of arginine (5.83 mg/100 g) passes into osmotic solution, which is involved in cleansing the liver and regulating the growth of muscle mass.

The sugar solution after osmotic dehydration of the *Sorbusaucuparia* berries (Fig. 1, *d*) receives 17 amino acids (32.97 mg/100 g), 8 of which are essential. The largest volume is demonstrated by the following amino acids, mg/100 g: serine (9.96), arginine (5.23), aspartic acid (3.3), threonine (2.52), valine (1.9), and leucine (0.97).

Our analysis revealed that a certain amount of amino acids passes into the derivative products from processing the *Hippophaerhamnoides L., Viburnumopulus, Sambucusnigra, Sorbusaucuparia* wild berries during osmotic dehydration. The use of these solutions to enrich sugar will increase its biological value.

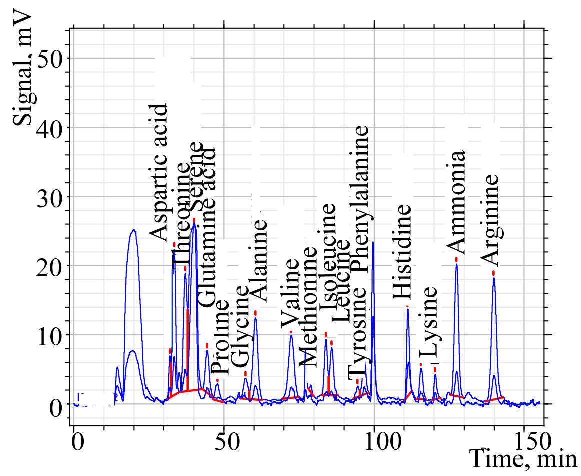

Fig. 4. Amino acid spectrum of the derivative product from processing *Sorbusaucuparia*

5. 2. Results of studying the organoleptic indicators of enriched sugar

The sugar enriched with derivatives from processing the *Viburnumopulus, Hippophaerhamnoides L., Sambucusnigra, Sorbusaucuparia* wild berries is shown in Fig. 5.

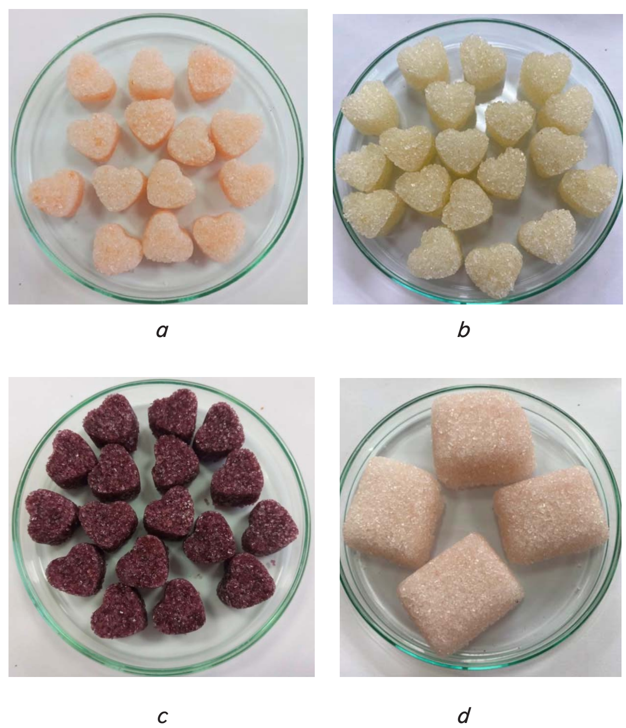

Fig. 5. Pressed sugar enriched with derivative products from processing wild berries: *a* – *Viburnum opulus*; *b* – *Hippophae rhamnoides L.*; *c* – *Sambucusnigra*; *d* – *Sorbusaucuparia*

The organoleptic evaluation showed that all enriched sugars had good sensory properties. The results are given in Table 2.

The highest score in all organoleptic indicators was given to sugar enriched with sea buckthorn (*Hippophae rhamnoides L.*). For the appearance, all samples were highly appreciated; however, the tasters noted that the size and shape of the pieces of sugar *a*, *b*, *c* are more acceptable than the sample *d*. Sugar solutions had no mechanical impurities.

Table 2

Results of the organoleptic evaluation of enriched sugar

Processing by-products	Physical appearance	Smell and taste	Solution purity
Viburnum opulus	10	9	10
Hippophae rhamnoides L.	10	10	10
Sambucus nigra	10	10	9
Sorbus aucuparia	9	10	10

6. Discussion of results of studying the impact of derivative products from processing wild berries on the quality of sugar

Serine, the largest amount of which was found in the derivative product from processing the Viburnumopulu wild berries, is involved in the formation of DNA and RNA molecules. It plays an important role in the metabolic reactions of the body, providing the synthesis of glycine and sulfur-containing amino acids. This amino acid is extremely important for the brain. Proline is found in large quantities in *Hippophaerhamnoides*. This amino acid is necessary for the formation of collagen in the body, which forms all connective tissues. Aspartic acid stimulates protein synthesis, reduces the level of ammonia in the blood, normalizes the work of the liver. Tyrosine is used for protein synthesis, formation of catecholamines, thyroid hormones, melanin. Deficiency of tyrosine leads to a lag in the physical development of children. Therefore, sugar enriched with *Sambucusnigra* will be especially useful for children. The valine and leucine found in all samples, including the derivatives from *Sambucusnigra* processing, are associated with hydrophobic interactions and are important for the assembly of the structure and three-dimensional conformation of proteins. Valin is involved in the main ways of synthesizing compounds responsible for the characteristic smell of fruits.

Our study showed that the addition of 10 % of osmotic solution of the accompanying product from processing the *Viburnum opulus, Hippophae rhamnoides L., Sambucus nigra, Sorbus aucuparia* wild berries to sugar made it possible to obtain sugar with good organoleptic indicators (Table 2). Similar results were reported by other scientists who enriched sugar with powdered herbal supplements (ginger, mint, raspberries). The most suitable berry raw material for sugar enrichment, according to their results, is raspberries [21]. It is worth noting that when using this technology, insoluble substances are added to sugar, which is a negative factor in the preparation of drinks.

The peculiarity of the proposed technology is a unique technique for processing wild berries, which makes it possible to remove from the fruit part such biologically valuable nutrients as amino acids, color substances, flavoring and aroma-forming substances.

Preliminary freezing of berries reduces their bitterness; an osmotic solution based on concentrated sugar solution formed after dehydration is a good additive for pressed sugar. The sensory characteristics of osmotic solutions have a positive effect on the organoleptic indicators of the finished sugar. All samples had a barely noticeable aroma of berries. Sample *a* had a specific, not pronounced, smell of guelder rose (*Viburnum opulus*). The most pronounced was the taste of sugar enriched with elderberry (*Sambucus nigra*). The purity of its solution was lower compared to other samples. In the sample with the addition of a derivative product from rowan processing (*Sorbus aucuparia*), there was a pleasant bitterness. Obviously, caused by the presence of sorbic acid in the osmotic solution.

The proposed solutions for the use of derivative products from processing wild berries can be used not only to produce pressed sugar but also for sand sugar.

Since sugar production is seasonal, the processing of wild berries and the production of enriched sugar should be organized in the spring-summer period. The ripening season of wild berries is autumn. However, according to the proposed technology, their preliminary freezing is assumed. In a frozen state, berries can be stored for several months, until the end of processing sugar beets. The implementation of this technology will ensure the work of a certain number of employees throughout the year. The apparatus for osmotic dehydration [19] occupies a small production area, it can be installed in the crystallization department. Mixing sugar with osmotic solution can be carried out in existing clarification mixers. Once enriched granulated sugar is produced, drying can be carried out in convective dryers available in production. In the case of its pressing, it becomes necessary to install additional equipment – carousel presses and tunnel dryers.

It is recommended to use 10 % of osmotic solution to the mass of crystalline sugar. To determine the need for berry raw materials, one needs to know the desired amount of enriched sugar. At the same time, create a stock of berries (5 % to this amount), since the ratio of sugar syrup and berries that is recommended during dehydration is 1:1.

The limitations of this study include the fact that there is no specialized equipment for osmotic dehydration. Under industrial conditions, without the availability of such equipment, it is difficult to maintain the necessary dehydration regimes of berries. However, the design of the apparatus for osmotic dehydration has already been developed [19], now this technological advancement is pending for a patent.

It is difficult to provide the expected practical results in the processing of berry raw materials outside the plant.

It is important to minimize the time from osmotic dehydration to sugar pressing. Storage of sugar solutions may be accompanied by a deterioration of their organoleptic properties and damage caused by the action of microorganisms.

Further research will be aimed at investigating the complete chemical composition of sugars enriched with derivative products from processing the *Viburnum opulus*, *Hippophae rhamnoides L.*, *Sambucus nigra*, *Sorbus aucuparia* wild berries.

7. Conclusions

1. Our analysis of the amino acid spectrum of related products from processing the *Hippophae rhamnoides L., Viburnum opulus, Sambucus nigra, Sorbus aucuparia* wild berries has revealed that as a result of osmotic dehydration, 17 amino acids, including essential ones, pass into the solution from berries. The lowest concentration of amino acids was found in the accompanying product from processing the *Viburnum opulus* wild berries (3.63 mg/100 g), and the largest – *Sambucus nigra* (55.47 mg/100 g).

2. All the samples of sugar enriched with related products from processing the *Hippophae rhamnoides L., Viburnum opulus, Sambucus nigra, Sorbus aucuparia* wild berries received a high organoleptic assessment. By all indicators (appearance, taste and smell, purity of solution), the highest score was given to sugar enriched with *Hippophae rhamnoides L*.

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